

References

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Table 1A

Symbols used for various mutations

1. Nutritional requirements. The allele for requirement, i.e., lack of synthesis of a substance is "-"; the alternative, independence, is "+".

| | | | | | |
|----------------|---------|---|------------|----|---------------|
| B | biotin | L | leucine | Pa | phenylalanine |
| B ₁ | thiamin | M | methionine | T | threonine |
| C | cystine | P | proline | | |

2. Sugar fermentation. The ability to ferment is "+"; the alternative, inability, is "-".

Lactose Lac

3. Bacteriophage resistance. Resistance is designated by the superscript "r"; sensitivity by "s".

V₁ reaction to bacteriophage T1
V₆ reaction to bacteriophage T6.

Table 1B

A Summary of the Mutants Used

| <u>Strain No.</u> | <u>Genotype</u> | <u>Origin</u> | <u>Genotype</u> | <u>Agent</u> |
|-------------------|---|-----------------------|---|--------------|
| K-12 | prototroph. | Original wild strain. | | |
| 58 | B- | K-12 | B+ | X-ray |
| 58-161 | B-M- | 58 | B-M+ | X-ray |
| 58-278 | B-Pa- | 58 | B-Pa+ | X-ray |
| Y-24 | B-Pa-C- | 58-278 | B-Pa-C+ | u.-v. |
| 679 | T- | K-12 | T+ | X-ray |
| 679-680 | T-L- | 679 | T-L+ | X-ray |
| Y-10 | T-L-B ₁ - | 679-680 | T-L-B ₁ + | X-ray |
| Y-46 | T-L-B ₁ -V ₁ ^r | Y-10 | T-L-B ₁ -V ₁ ^s | selection |
| Y-53 | T-L-B ₁ -Lac- | Y-10 | T-L-B ₁ -Lac+ | u.-v. |
| Y-64 | T-L-B ₁ -Lac-V ₁ ^r | Y-53 | T-L-B ₁ -Lac-V ₁ ^s | selection |
| Y-40 | B-M-V ₁ ^r | 58-161 | B-M-V ₁ ^s | selection |
| Y-87 | B-M-V ₁ ^r Lac- | Y-40 | B-M-V ₁ ^r Lac+ | N-mustard |
| Y-25 | B-Pa-C-V ₁ ^r | Y-24 | B-Pa-C-V ₁ ^s | selection |
| 679-183 | T-P- | 679 | T-P+ | X-ray |
| Y-94 | T-L-B ₁ -Lac-V ₆ ^r | Y553 | T-L-B ₁ -Lac-V ₆ ^s | selection |

Table 2.

Biochemical recombination types found in a mixed culture
of Y-24 and Y-46.



| Type: [*] | No. | No. of | Ratio |
|---------------------------|------------------------------|-------------|-------|
| B Pa C T L B ₁ | isolated | prototrophs | |
| - - - + + + | In excess: parental type | | |
| + + + - - - | In excess: parental type | | |
| + + + + + + | 86 | -- | -- |
| + + + + + - | 36 | 37 | 0.97 |
| + + + - + + | 2 | 31 | 0.06 |
| + + + + - + | 4 | 55 | 0.07 |
| - + + + + + | 5 | 56 | 0.09 |
| + - + + + + | 1 | 52 | 0.02 |
| + + - + + + | 1 | 19 | 0.05 |
| - - + + + + | 2 | 41 | 0.05 |
| + + + + - - | 3 | 16 | 0.19 |
| - + + + + - | 3 | 28 | 0.11 |
| - + + - + + | isolated in a different run. | | |
| - + + + - + | isolated in a different run. | | |

*These figures do not include tests of the V₁ character. Of 49 prototrophs tested, 20 (41%) were resistant. Of 20 thiamin-less tested, 7 (35%) were V₁^R.

Table 3.

Comparisons of V_1^r segregations with alternative parental couplings.

| Parents | | Prototrophs isolated | | | | |
|-----------------------------|-----------------------------|----------------------|---------|-----------|-------------|-------------|
| B-Pa-C-T+P+ | B+PatC+T+P- | V_1^r | V_1^s | % V_1^r | $\chi^2(1)$ | $\chi^2(2)$ |
| $V_1^r X$ | V_1^s | 76 | 6 | 92 | | |
| $V_1^s X$ | V_1^r | 30 | 107 | 22 | 101 | 7.9 |
| B-Pa-C-T+L+B ₁ + | B+PatC+T-L-B ₁ - | | | | | |
| $V_1^r X$ | V_1^s | 80 | 23 | 77 | | |
| $V_1^s X$ | V_1^r | 53 | 133 | 28 | 65 | 1.1 |
| B-M-T+P+ | B+M+T-P- | | | | | |
| $V_1^r X$ | V_1^s | 49 | 8 | 86 | | |
| $V_1^s X$ | V_1^r | 5 | 19 | 21 | 32 | 1.8 |

$\chi^2(1)$ refers to a comparison of the classes directly: i. e., to a 2×2 table of the data as they stand.

$\chi^2(2)$ refers to a comparison in which the gametic output or V_1^r is inverted in the same manner as was done by changing the parental coupling. In both cases, $n = 1$ for each table. The cumulative χ^2 are 198 and 10.8 respectively.

Table 4a.

Data of individual experiments. Lac, V, scores on colonies isolated from minimal agar plates in the cross: Y40 x Y53

B-M-T+L+B₁+Lac+V₁^r x B+M+T-L-B₁-Lac-V₁^s

Class recovered: B+M+T+L+B+...

| Exp. # | Lac-V ₁ ^r | Lac-V ₁ ^s | Lac+V ₁ ^r | Lac+V ₁ ^s |
|--------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1. | 51 | 11 | 23 | 4 |
| 2. | 28 | 21 | 21 | 0 |
| 3. | 21 | 18 | 11 | 0 |
| 4. | 189 | 44 | 129 | 3 |
| 5. | 52 | 39 | 39 | 2 |
| 6. | 17 | 10 | 9 | 0 |
| 7. | 35 | 30 | 35 | 0 |
| 8. | 20 | 22 | 10 | 3 |
| 9. | 37 | 23 | 16 | 1 |
| 10. | 20 | 13 | 15 | 2 |
| 11. | 26 | 9 | 11 | 3 |
| 12. | 19 | 10 | 11 | 2 |
| 13. | 27 | 12 | 30 | 1 |
| 14. | 27 | 13 | 13 | 1 |
| 15. | 33 | 28 | 14 | 0 |
| Total | 602 | 303 | 387 | 22 |
| % | 45.8 | 23.1 | 29.4 | 1.7 |

Homogeneity: $\chi^2 = 101.$, n = 42. p < .001

Table 4 b.

Data of individual experiments. Lac, V₁ scores on colonies isolated from thiamin-supplemented plates in the cross Y 40 x Y53.

B-M-T+L+B₁+Lac+V₁^r x B+M+T-L-B₁-Lac-V₁^s

Class recovered: B+M+T+L+B₁- ca. 10% B₁-.

| Exp. | Lac-V ₁ ^r | Lac-V ₁ ^s | Lac+V ₁ ^r | Lac+V ₁ ^s |
|-------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1. | 30 | 21 | 17 | 1 |
| 2. | 73 | 46 | 50 | 4 |
| 3. | 27 | 12 | 30 | 1 |
| 4. | 59 | 34 | 31 | 3 |
| 5. | 16 | 12 | 13 | 0 |
| 6. | 21 | 19 | 5 | 0 |
| 7. | <u>18</u> | <u>12</u> | <u>13</u> | <u>1</u> |
| Total | 244 | 156 | 159 | 10 |
| % | 42.9 | 27.4 | 27.9 | 1.8 |

Homogeneity: $\chi^2 = 16.9$ n = 18, p = .5

Homogeneity of B₁+ totals with B₁- totals (Tables 4a & 4 b)

| | | | | |
|------------|------------|------------|-----------|------------|
| 602 | 303 | 387 | 22 | 1314 |
| <u>244</u> | <u>156</u> | <u>159</u> | <u>10</u> | <u>569</u> |
| 846 | 459 | 546 | 32 | 1883 |

$\chi^2 = 4.4$

With a normal distribution of χ^2 , p would be 0.2. In view of the heterogeneity of the B₁+ data however, this result is artificially low.

Table 4 c.

Data of individual experiments. Lac, V scores on colonies isolated from minimal agar in the cross: Y 64 x 58-161.

B-M-T+L+B₁+Lac+V₁^s x B-M+T-L-B₁-Lac-V₁^r

Class recovered: B-M-T-L-B₁-.....

| Exp. | Lac-V ₁ ^r | Lac-V ₁ ^s | Lac+V ₁ ^r | Lac+V ₁ ^s | Sum |
|-------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-----|
| 1. | 37 | 55 | 5 | 19 | 116 |
| 2. | 42 | 53 | 1 | 23 | 119 |
| 3. | 8 | 9 | 1 | 2 | 20 |
| 4. | 13 | 16 | 1 | 9 | 39 |
| 5. | 8 | 12 | 1 | 8 | 29 |
| Total | 108 | 145 | 9 | 61 | 323 |
| % | 33.4 | 45.0 | 2.8 | 18.9 | |

Homogeneity: $\chi^2 = 5.6$ n = 12. p = .95.

Table 4d.

As above, scores on colonies isolated from thiamin-supplemented agar

Class recovered: B+M+T+L+B₁- + ca. 10% B₁+

| | | | | | |
|-------|------|------|-----|------|-----|
| 1. | 109 | 125 | 8 | 70 | 312 |
| 2. | 20 | 21 | 1 | 9 | 51 |
| 3. | 4 | 5 | 0 | 1 | 10 |
| Total | 133 | 151 | 9 | 80 | 373 |
| % | 35.6 | 40.5 | 2.4 | 21.4 | |

Homogeneity: $\chi^2 = .65$ n = 3, p = .85 (expts. 1 & 2 only)

Comparison of 4c and 4d totals (B₁+ with B₁-)

| | | | | | |
|----|------------|------------|----------|-----------|------------|
| 4d | 133 | 151 | 9 | 80 | 373 |
| 4e | <u>108</u> | <u>145</u> | <u>9</u> | <u>61</u> | <u>323</u> |
| | 241 | 196 | 18 | 141 | 696 |

$\chi^2 = 1.7$ n = 0.6

Table 4e

Lac, V_1 scores on colonies isolated from minimal agar in
the cross: Y87 X Y10. B.

$B+M+T+L+B_1+Lac-V_1^R \times B+M+T-L-B_1-Lac+V_1^S$

Class recovered: $B+M+T+L+B_1+\dots$

Single Experiment.

| $Lac-V_1^R$ | $Lac-V_1^S$ | $Lac+V_1^R$ | $Lac+V_1^S$ | Total |
|-------------|-------------|-------------|-------------|-------|
| 28 | 6 | 46 | 57 | 117 |
| % 23.9 | 5.1 | 39.3 | 31.6 | |

Table 4f

As above. Isolates from thiamin agar.

| Class recovered: | $B+M+T+L+B_1-$ | $+ 10\% B_1+$ | |
|------------------|----------------|---------------|------|
| 102 | 7 | 201 | 91 |
| % 25.4 | 1.7 | 50.1 | 22.7 |

Comparison of 4e and 4f (B_1+ with B_1-)

| | | | | |
|-----|----|-----|-----|-----|
| 28 | 6 | 46 | 37 | 117 |
| 102 | 7 | 201 | 91 | 401 |
| 130 | 13 | 247 | 128 | 518 |

$\chi^2 = 8.2$, $n = 3$, $p = .04$.

Table 4g

Tests of allelism of mutations at Lac and V loci.

1. Test of allelism of Lac- in stocks Y53 and Y87.

B+M+T-L-B₁-Lac- x B-M-T+L+B₁-Lac-. 134 prototrophs isolated: all Lac-.

2. Test of allelism of V₁^r in stocks Y40 and Y-46

B-M-T+L+B₁+Lac+V₁^r X B+M+T-L-B₁-Lac-V₁^r
161 prototrophs isolated: all V₁^r

128 Lac- ; 33 Lac+.

Table 5
Summary of Tables 4.

The segregation of Lac and V into "prototrophs" derived from various crosses. Scores of B_1^+ and B_1^- classes have been pooled in view of their homogeneity.

| Parents | | Recombinants: $B^+M^+T^+L^+B_1^\pm$ | | | | | Total |
|------------------------------------|---------------------------------|-------------------------------------|---------------------------------|---------------------------------|---------------------------------|------------|-------|
| $B^+M^+T^+L^+B_1^+$ | $B^+M^+T^-L^-B_1^-$ | Lac-V ₁ ^r | Lac-V ₁ ^s | Lac+V ₁ ^r | Lac+V ₁ ^s | | |
| A. Lac-V ₁ ^r | Lac-V ₁ ^s | 846 % | 459 24.4 | 546 29.0 | 32 1.7 | 1883 | |
| B. Lac-V ₁ ^s | Lac-V ₁ ^r | 241 % | 296 42.5 | 18 2.6 | 141 20.3 | 696 | |
| C. Lac-V ₁ ^r | Lac-V ₁ ^s | 130 % | 13 2.5 | 247 47.7 | 128 24.7 | <u>518</u> | |
| | | | | | | 3097. | |

The 3x4 contingency tables of Table 5 gives the following χ^2 Value (for 6 degrees of freedom.)

$$\chi^2 = 777.3$$

Table 6.

The data of Table 5. are rearranged so as to bring corresponding interchange classes in the same column.

B-M-T+L+B₁+Lac x V₁y X B+M+T+L-B₁-Lac x' V₁y'

| Parents | Class recovered: B+M+T+L+... | | | | | | | | |
|------------|------------------------------|-------------|-------------|-------------|-------------|-----------|-----------|-----|-------|
| | x | y | x' | y' | x'y' | xy' | xy | x'y | Total |
| ab + r - s | 546 (29.) | | 646 (44) | | 459 (24) | | 32 (2) | | 1883 |
| cd + s - r | | 141 (20) | | 296 (42) | 241 (35) | 18 (3) | | | 696 |
| ef - r + s | | 130 (25) | | 247 (48) | 128 (25) | 13 (2) | | | 518 |
| Totals | 817 | 1389 | 828 | 63 | | | | | 3097 |
| % | 26.4 | 44.8 | 26.8 | 2.0 | | | | | |
| s | .270 | : .458 | : .273 | --- | a | b | c | | |

$\chi^2 = 40.7$, $n = 6$. No true value of p can be calculated because of the inconsistent variance of the different populations. Compare, however, with the value of $\chi^2 = 777$ of Table 5.

The figures in parentheses are the percent contribution of each class to the row total. "s" are the proportions of the single interchanges according to the map:

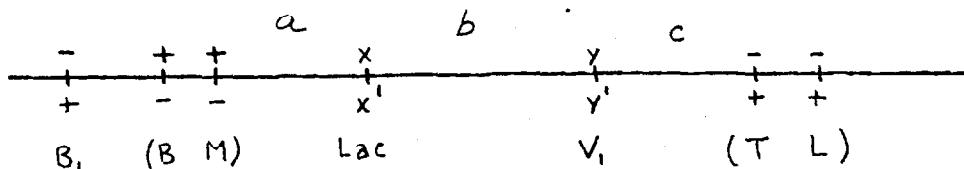


Table 7

RELATIVE FREQUENCY OF VARIOUS BIOCHEMICAL RECOMBINATION CLASSES
IN THE CROSS

B-M-T+L+B₁+ x B+M+T-L-B₁- *

| From plates supplemented with | Number of colonies tested | Recombination classes found | | | | | | χ^2 |
|-------------------------------------|---------------------------------|-----------------------------|--------|------------------|--------|-------|----|----------|
| | | Type | Number | Type | Number | Ratio | | |
| Biotin | 70 | B- | 10 | B+ | 60 | 0.17 | 36 | |
| Threonine | 46 | T- | 9 | T+ | 37 | 0.24 | 17 | |
| Leucine | 56 | L- | 5 | L+ | 51 | 0.096 | 38 | |
| Thiamin | 87 | B ₁ - | 79 | B ₁ + | 8 | 9.88 | 56 | |

* Cells of the parental types were mixed and plated into agar supplemented with the growth factor indicated. On this medium, the two recombination classes indicated on each line of the table could form colonies. Contrasting alleles only are specified; other loci, unless otherwise specified, have the "+" configuration. The χ^2 for the ratio of single biochemical deficient types, types to prototrophs is calculated for a comparison with the 1:1 expectation of a random segregation. As can be seen from the χ^2 values, the probability that the deviations are due solely to chance is, in each case, less than .001.

Table 8

SEGREGATION OF Lac, V₁ and V₆

B-M-T+L+B₁+Lac+V₁^rV₆^s x B+M+T-L-B₁-Lac-V₁^sV₆^r

| B-M-T+L- | Lac: | - | - | - | - | + | + | + | + | To- |
|---------------------|------|----|-----|-----|---|-----|-----|-----|-----|-----|
| V ₁ : | r | s | r | s | r | s | r | s | s | tal |
| V ₆ : | r | r | s | s | r | r | s | s | | |
| ...B ₁ + | | 24 | 16 | 1 | 0 | 2 | 1 | 10 | 2 | 56 |
| ...B ₁ - | | 52 | 42 | 2 | 0 | 6 | 1 | 16 | 1 | 120 |
| Total | | 76 | 58 | 3 | 0 | 8 | 2 | 26 | 3 | 176 |
| % | | 43 | 33 | 1.7 | 0 | 4.6 | 1.1 | 15 | 1.7 | |
| Crossover region | e | f | cde | cdf | d | def | c | ced | | |

B₁_a..B₂_b..M_c..V₆_d..Lac_e..V₁_f..T..L *

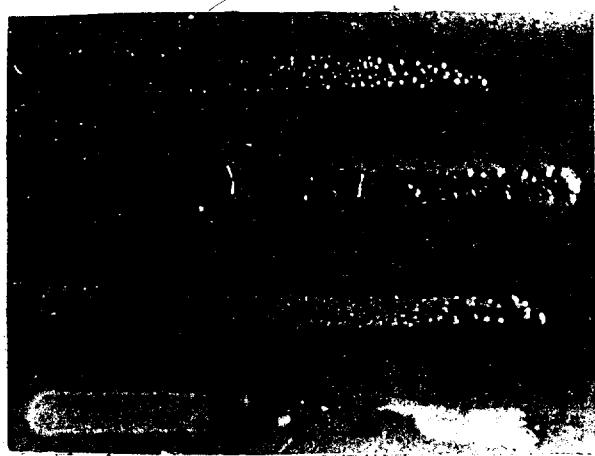
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| + | - | - | s | + | r | + | + |
| - | + | + | r | - | s | - | - |

*This map is not intended to represent the map distances,
merely the linear order.

Table 9

Pairwise Occurrence of Recombination in Mixtures of Three Components

| Parental Types | | Recombinant Prototrophs | | | | |
|---------------------------------|---------------------------------|--|---------------------------------|---------------------------------|---------------------------------|------|
| B-M-T+L+B ₁ + | B+M+T-L-B ₁ - | B+M+T+L+B ₁ - or B ₁ + | | | | |
| Lac-V ₁ ^r | Lac+V ₁ ^r | Lac-V ₁ ^r | Lac-V ₁ ^s | Lac+V ₁ ^r | Lac+V ₁ ^s | Tot |
| Lac-V ₁ ^r | Lac+V ₁ ^r | 173 | 49 | 4 | 0 | 226 |
| Lac+V ₁ ^s | Lac+V ₁ ^r | 0 | 136 | 37 | 40 | 213 |
| Lac+V ₁ ^s | Lac-V ₁ ^s | 65 | 48 | 0 | 25 | 138 |
| Lac+V ₁ ^r | Lac-V ₁ ^r | 16 | 0 | 7 | 28 | 51 |
| Total..... | | | | | | 628. |



Caption for Fig. 1.

Fig. 1. The phenotypes of the four combinations of Lac and V are illustrated. In order they are: Lac+V₁^R; Lac+V₁^S; Lac-V₁^R; Lac-V₁^S. An EMB-lactose agar plated was first streaked vertically with the virus T1. Subsequently, each of the bacteria was streaked, from left to right, perpendicularly across the virus streak. After 16 hours incubation, both the Lac and V₁ phenotypes are well developed. Developing in the zone where Lac-V₁^S has been lysed can be seen two colonies of resistant mutants: Lac-V₁^R.